# The 20th Annual David S. Snipes/Clemson Hydrogeology Symposium Field Trip Guidebook

# Connections between Geology and Plant Communities in the Eastatoe Valley, SC

Maidenhair Ferns on Amphibolite

Christmas Ferns and Galax on Gneiss

Tom Goforth examining Silver Glade Ferns in Paw Paw Creek

**Field Trip Leaders: Tom Goforth, Jack Garihan, and Scott Brame**

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# Connections between Geology and Plant Communities in the Eastatoe Valley, SC

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**Abstract**

About 400 million years ago sufficient oxygen accumulated in earth's atmosphere to form ozone in the stratosphere. Organisms were then able to venture onto land that was covered by diverse rock types, weathered soils, topography, and climate regimes. They were presented with a plethora of niche choices in which to seek sustenance and stability. In this process, they faced multiple challenges connecting with, adapting to, and cooperating with different habitat conditions.

The mineralogy and structure of bedrock geology are the basis for the physical and chemical conditions of habitats in which terrestrial organisms reside. Where different substrate lithologies (rock units) are juxtaposed at the surface, variations occur in both soil chemistry and in the resulting communities of plants and animals. Primary and secondary weathering produces soils that contain cations, anions, stable minerals, and unstable minerals. Topographical controls on hydrology influence the migration of these ions producing both sharp and gradational zones of soil chemistry that correspond to drainage patterns.

Microscopic and megascopic organisms have adapted to the geology and diverse soils they produce as (1) specialists in a specific habitat, (2) specialists in a narrow range of habitats, or (3) cosmopolitans (non-specialists) across widely different habitats. This field trip focuses on connections between habitat, geology, soil chemistry, and plant species. By visiting specific sites in the Jocassee Gorges region with different geology conditions, participants will become acquainted with specialist plant species and conduct short investigative surveys using plant occurrences and soil pH as indicators to infer substrate lithology in the absence of outcrops.

**The Community Effect**

A community is a grouping of living (plants, animals) and non-living (soil, rock, water) components in a regime of thermal, electromagnetic, chemical, and light energies. Each member of a community displays behaviors based on its characteristics, the characteristics and behaviors of other community members, and the amount of available energy. Individual interaction with other community members is variable. An exhaustive survey of a community shows that most members interact with other members either continually or rhythmically, and have preferences for specific members. At an elemental level, hydrogen for example is highly interactive while typically non-reactive elements (like gold) have minimal interactions. Quartz is very stable and resistant to both chemical and mechanical weathering in contrast with biotite which is subject to intense chemical weathering at near surface conditions. An intermittent community member, such as a fox, has variable community associations while a redwood seedling may have substantial continual influence on its community for 1000's of years.

Connections between members of a particular community are numerous, complex, variable, and sometimes very old or quite new. Community composition evolves and changes over time

as interactions are altered through the influences of introduced, lost, and persistent community members and variations in energy. Some communities can maintain stability over long periods of time in the absence of catastrophic events that can radically alter the community structure. Examples of catastrophic events are large earthquakes, climate change, the introduction of invasive species, severe weather events, and significant human disturbances. When radical changes occur, remaining and new community members reorganize their interactions and create a new community structure. Currently, our knowledge and understanding of these complex interactions is limited. Only by continuing to pursue increasingly sophisticated and detailed investigations will we be able to understand the actual connections, causes, and effects.

## Geologic Connections with Native Plants

Botanists have long recognized the connection between plant occurrences and substrate geology. They typically include either general site geology or regional geologic information in plant survey and other biological literature. Plants have adapted and are adapting to variable soil chemistry that is derived from substrate lithologies, sediments, and aqueous solutions transported locally or from afar. Some plant species, called specialists, occur exclusively in habitats with soils derived from specific rock types. Non-specialist plants, called cosmopolitans, occur in multiple habitats with variable substrates. Where vigorous growing specialists are observed in a habitat, the substrate can be inferred as occurring in close proximity. Infrequent and stunted plant species may be encountered within a substrate that does not normally support that species.

Along a transect where variable substrate lithologies are exposed, different plant specialists occur that reflect the different minerals and soils produced by the weathering of a particular rock type. Plant specialists and the soils in which they reside can be used as indicators of substrate when outcrops are few or absent. Lithologic contacts are sometimes slightly to moderately blurred by the effects of local topography, hydrology, sedimentation, or metasomatism in metamorphic terrain. Human land use may significantly modify and even preclude making geologic/plant correlations where soil profiles have been lost, depleted, or artificially amended.

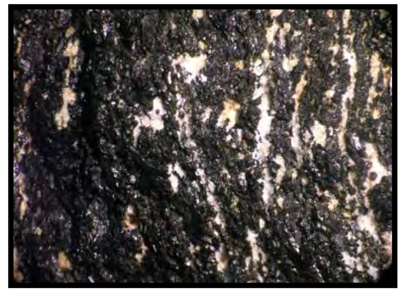
## Bedrock Mineralogy

Bedrock mineralogy is the primary source of surface soil. The composition and characteristics of the soil directly influences the variety of organism and the habitat composition.

The Inner Piedmont of South Carolina is underlain by felsic, mafic, and intermediate metamorphic rocks composed chiefly of alumino-silicate minerals. Mineralogy of rock units varies primarily in metal content. Metals are key components in soil character development, pH, community structure, and plant vigor. Figure 1 lists the general mineralogy of three rock types that will be encountered in this field trip. The percentage of metals in the minerals found in each rock type varies which influences the soil characteristics and the availability of plant nutrients. In general, mafic rocks produce richer soils and higher plant diversity compared to felsic rocks.

**Poor Mountain amphibolite (mafic)**

Hornblende….$(Ca,Na)_{2-3}(Mg,Fe,Al)_5\ Si_6(Si,Al)_2O_{22}(OH)_2$
Anorthite….$CaAl_2Si_2O_8$
Quartz….$SiO_2$
Biotite….$K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$
Epidote….$Ca_2(Al,Fe)Al_2O(SiO_4)(Si_2O_7)(OH)$



**Henderson Gneiss/Table Rock gneiss (felsic)**

Orthoclase....$KAlSi_3O_8$
Quartz….$SiO_2$
Muscovite….$KAl_2(AlSi_3O_{10})(OH)_2$
Biotite….$K(Mg,Fe)_3(AlSi_3O_{10}(OH)_2$

**Chauga River Formation (intermediate)**

Muscovite….$KAl_2(AlSi_3O_{10})(OH)_2$
Biotite….$K(Mg,Fe)_3(AlSi_3O_{10}(OH)_2$
Almandine….$Fe_3Al_2Si_3O_4$
Orthoclase....$KAlSi_3O_8$
Quartz….$SiO_2$

-

**Figure 1**. Dominant rock types and mineral assemblages encountered in the field trip area

## Weathering

Substrate weathering is both mechanical and chemical. It depends on the availability of water and its acidity, oxygen, carbon dioxide, nitrogen, micro-organisms, higher organisms, and humus. Mineral components of rocks weather at different rates (Table 1).

**Table 1**. Relative weathering potential of different minerals

| Rock Type | Weathering Potential |
| --- | --- |
| Quartz and Muscovite | Very Slow |
| Feldspars and Biotite | Slow |
| Calcite, Hornblende, and Augite | Rapid |

In a mature forest setting weathering creates a typical soil profile as depicted in Figure 2. Many components of soil, including solids, dissolved ions, and molecules are mobile in the soil column both vertically and laterally. Plants absorb nutrients from the soil for metabolism and

growth and then return those nutrients initially as leaf litter and finally as dead plant stems and roots. Since plants can only absorb simple mineral compounds and ions, the organic molecules and complex minerals must be decomposed by micro-organisms to make them available for uptake by plants. Weathering proceeds through the formation of new minerals, acids, bases, and oxides, the release of stable minerals (such as quartz), and ultimately exchangeable cations and anions that are available to plants.

The activities of soil micro-organisms and fungi are largely responsible for late stage chemical weathering and the recycling of dead organic matter. In mature O and A horizons in a forest, upwards of 11 trillion micro-organisms exist in a space of one square meter that is 15 centimeters deep. These organisms consume and decompose dead organic matter and change organic molecules into molecules and ions. The byproducts of micro-organism activity are organic acids that facilitate the breakdown of clays and the release of ions strongly bound to clays.

In a mature soil profile, cation concentration is highest in the A horizon. Some of those cations migrate down into the B horizon where most are bound to clays. In this situation, surplus cations buffer the pH of the B horizon (causing a slight increase in pH).

If the O and A horizons, which includes the majority of micro-organisms, are removed through erosion or human development, the pH and richness of the surface soil will be lowered and the occurrences of substrate specific plants will be strongly inhibited. This is particularly true in mafic substrate terrain. The photos in Figure 3 are examples of this phenomenon. The photo on the left shows acid loving yellow pines growing above Poor Mountain amphibolite where the B horizon pH is ~5.5. The thin layer of surface soil has a pH ~5.6. If mature A horizon soil was present, the pH would be 6.7+, and pines would be absent. The photo on the right shows yellow pines growing above Table Rock Gneiss which is typical. In photo (b) the C horizon pH is 4.8, and the depleted forest floor soil pH is 5.0.

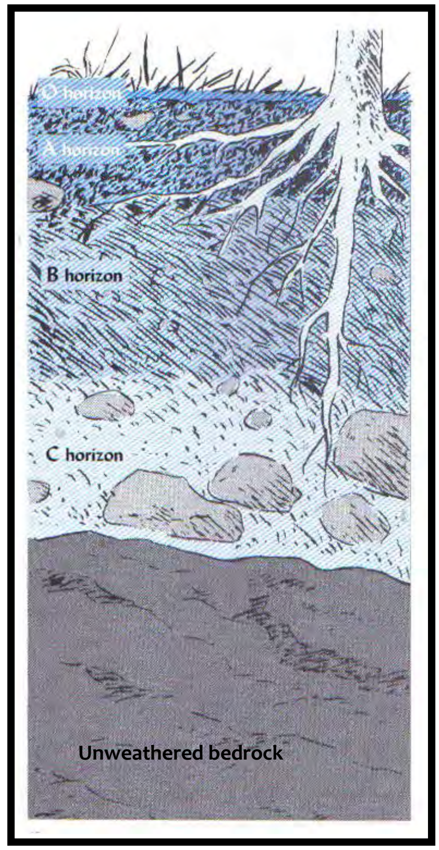


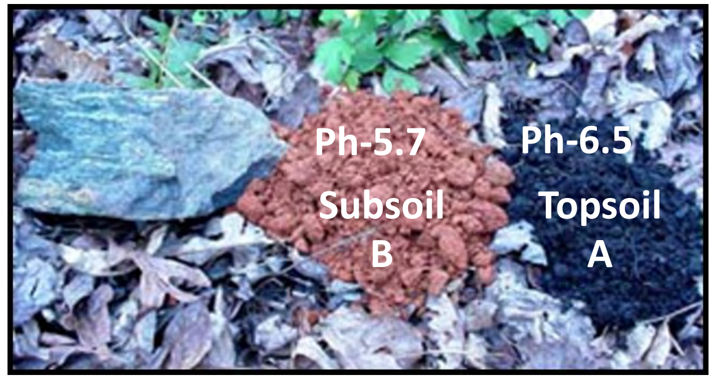

**Figure 2**. Soil weathering profile

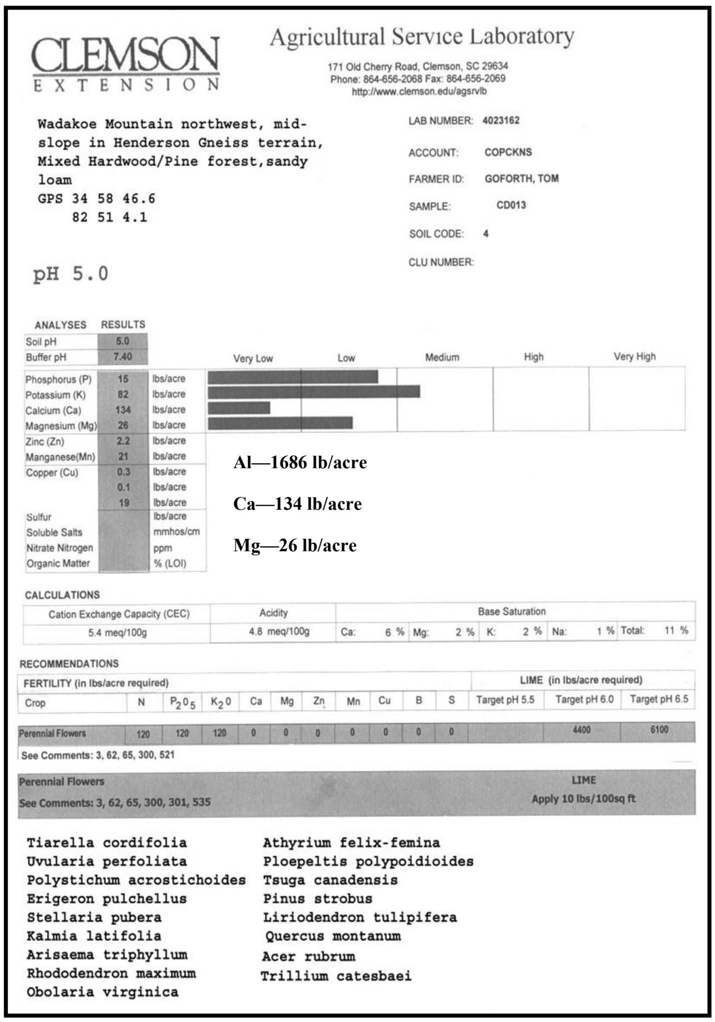
(a) (b)

**Figure 3**. Loss of the O and A horizons at sites underlain by (a) Poor Mountain amphibolite and (b) Table Rock gneiss

## Substrate Mineralogy Imprint on Soils

Soil analyses were performed on A and B horizon soils collected on the northwest side of Wadakoe Mountain in forests with mature soil profiles (Figure 4). The analyses show a direct correlation between substrate mineral assemblages (listed in Figure 1) and soil composition.

CLEMSON EXTENSION

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Wadakoe Mountain northwest, mid-slope in Henderson Gneiss terrain, Mixed Hardwood/Pine forest, sandy loam
GPS 34 58 46.6
82 51 4.1

LAB NUMBER: 4023162
ACCOUNT: COPCKNS
FARMER ID: GOFORTH, TOM
SAMPLE: CD013
SOIL CODE: 4
CLU NUMBER:

pH 5.0

| ANALYSES | RESULTS | |
|---|---|---|
| Soil pH | 5.0 | |
| Buffer pH | 7.40 | |
| Phosphorus (P) | 15 | lbs/acre |
| Potassium (K) | 82 | lbs/acre |
| Calcium (Ca) | 134 | lbs/acre |
| Magnesium (Mg) | 26 | lbs/acre |
| Zinc (Zn) | 2.2 | lbs/acre |
| Manganese(Mn) | 21 | lbs/acre |
| Copper (Cu) | 0.3 | lbs/acre |
| | 0.1 | lbs/acre |
| | 19 | lbs/acre |
| Sulfur | | lbs/acre |
| Soluble Salts | | mmhos/cm |
| Nitrate Nitrogen | | ppm |
| Organic Matter | | % (LOI) |

Very Low · Low · Medium · High · Very High

**Al—1686 lb/acre**

**Ca—134 lb/acre**

**Mg—26 lb/acre**

CALCULATIONS

| Cation Exchange Capacity (CEC) | Acidity | Base Saturation | | | | |
|---|---|---|---|---|---|---|
| 5.4 meq/100g | 4.8 meq/100g | Ca: 6 % | Mg: 2 % | K: 2 % | Na: 1 % | Total: 11 % |

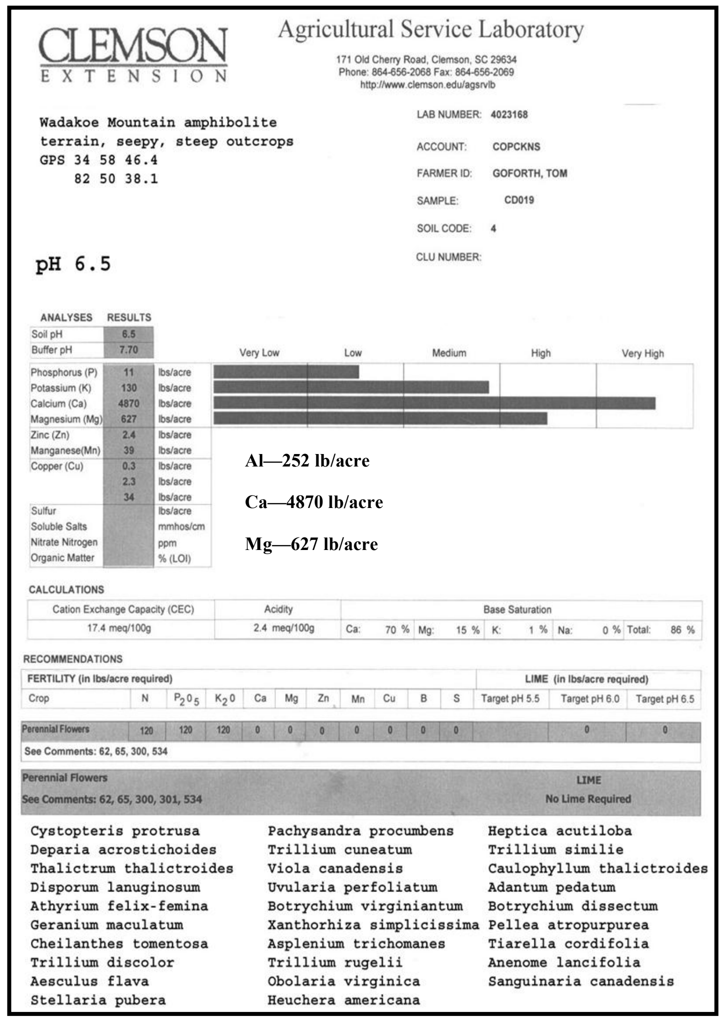
RECOMMENDATIONS

| FERTILITY (in lbs/acre required) | | | | | | | | | | | LIME (in lbs/acre required) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crop | N | $P_2O_5$ | $K_2O$ | Ca | Mg | Zn | Mn | Cu | B | S | Target pH 5.5 | Target pH 6.0 | Target pH 6.5 |
| Perennial Flowers | 120 | 120 | 120 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 4400 | 6100 |

See Comments: 3, 62, 65, 300, 521

Perennial Flowers
See Comments: 3, 62, 65, 300, 301, 535
LIME
Apply 10 lbs/100sq ft

Tiarella cordifolia
Uvularia perfoliata
Polystichum acrostichoides
Erigeron pulchellus
Stellaria pubera
Kalmia latifolia
Arisaema triphyllum
Rhododendron maximum
Obolaria virginica
Athyrium felix-femina
Ploepeltis polypoidioides
Tsuga canadensis
Pinus strobus
Liriodendron tulipifera
Quercus montanum
Acer rubrum
Trillium catesbaei



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Wadakoe Mountain amphibolite terrain, seepy, steep outcrops
GPS 34 58 46.4
82 50 38.1

LAB NUMBER: 4023168
ACCOUNT: COPCKNS
FARMER ID: GOFORTH, TOM
SAMPLE: CD019
SOIL CODE: 4
CLU NUMBER:

pH 6.5

| ANALYSES | RESULTS | |
|---|---|---|
| Soil pH | 6.5 | |
| Buffer pH | 7.70 | |
| Phosphorus (P) | 11 | lbs/acre |
| Potassium (K) | 130 | lbs/acre |
| Calcium (Ca) | 4870 | lbs/acre |
| Magnesium (Mg) | 627 | lbs/acre |
| Zinc (Zn) | 2.4 | lbs/acre |
| Manganese(Mn) | 39 | lbs/acre |
| Copper (Cu) | 0.3 | lbs/acre |
| | 2.3 | lbs/acre |
| | 34 | lbs/acre |
| Sulfur | | lbs/acre |
| Soluble Salts | | mmhos/cm |
| Nitrate Nitrogen | | ppm |
| Organic Matter | | % (LOI) |

Very Low · Low · Medium · High · Very High

**Al—252 lb/acre**

**Ca—4870 lb/acre**

**Mg—627 lb/acre**

CALCULATIONS

| Cation Exchange Capacity (CEC) | Acidity | Base Saturation | | | | |
|---|---|---|---|---|---|---|
| 17.4 meq/100g | 2.4 meq/100g | Ca: 70 % | Mg: 15 % | K: 1 % | Na: 0 % | Total: 86 % |

RECOMMENDATIONS

| FERTILITY (in lbs/acre required) | | | | | | | | | | | LIME (in lbs/acre required) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crop | N | $P_2O_5$ | $K_2O$ | Ca | Mg | Zn | Mn | Cu | B | S | Target pH 5.5 | Target pH 6.0 | Target pH 6.5 |
| Perennial Flowers | 120 | 120 | 120 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |

See Comments: 62, 65, 300, 534

Perennial Flowers
See Comments: 62, 65, 300, 301, 534
LIME
No Lime Required

Cystopteris protrusa
Deparia acrostichoides
Thalictrum thalictroides
Disporum lanuginosum
Athyrium felix-femina
Geranium maculatum
Cheilanthes tomentosa
Trillium discolor
Aesculus flava
Stellaria pubera
Pachysandra procumbens
Trillium cuneatum
Viola canadensis
Uvularia perfoliatum
Botrychium virginiantum
Xanthorhiza simplicissima
Asplenium trichomanes
Trillium rugelii
Obolaria virginica
Heuchera americana
Heptica acutiloba
Trillium similie
Caulophyllum thalictroides
Adantum pedatum
Botrychium dissectum
Pellea atropurpurea
Tiarella cordifolia
Anenome lancifolia
Sanguinaria canadensis

**Figure 4**: Soil Analyses from mature soil profiles collected from the northwest side of Wadako Mountain

## Native Plant Indicator Species

Mafic rocks produce circum-neutral pH soils and felsic rocks produce strongly acidic soils (ph values in soil analyses in Figure 4). The soil components most responsible for pH are acidic metals (Al) and alkaline metals (Ca, Mg, Mn, Na, and K). The relative proportions of these metals in the substrate mineralogy determine soil pH. Surface soil characteristics are a function of soil maturity and disturbance.

Plant specialist species that require strongly acid soils are called acidophiles, and specialist species that require low acidity or circum-neutral conditions are called calciphiles. Plants that occur in many different substrate terrains are cosmopolitans. The following pages contain photos (Figures 5, 6, 7, 8, and 9) of specialist species that are likely to be observed in felsic or mafic terrains.

**A mafic terrane with Northern Maidenhair Fern as the indicator species**

**A felsic terrane with New York Fern as the indicator species**

**Figure 5**. Mafic and felsic terranes that support markedly different plant communities.

**Royal Fern**
**Osmunda regalis**

**New York Fern**
**Thelypteris noveboracensis**

**Robin's Plaintain**
**Erigeron pulchellus**

**Mountain Laurel**
**Kalmia latifolia**

**Canadian Hemlock**
**Tsuga canadensis**

**Catesby's Trillium**
**Trillium catesbaei**

**Figure 6**. Indicator Species: Felsic Terrain, Low pH 4.6-5.2


**Azaleas**
**Rhododendron spp**

**Pines**
**Pinus spp**

**Galax**
**Galax urceolata**

**Cinnamon Fern**
**Osmunda cinnamomea**

**Yellowroot**
**Xanthorhiza simplicissima**

**Blueberry**
**Vaccinium spp**

**Figure 7**. Indicator Species: Felsic Terrain, Low pH 4.6-5.2

**Northern Maidenhair Fern**
**Adiantum pedatum**

**Acute leaf Hepatica**
**Hepatica acutiloba**

**Paw Paw**
**Asimina triloba**

**Narrow Glade Fern**
**Diplazium pycnocarpon**

**Redbud**
**Cercis canadensis**

**Wild Geranium**
**Geranium maculatum**

**Figure 8**. Indicator Species: Mafic Terrain pH 6.5-7.0+

**Spice Bush**
**Lindera benzoin**

**Broad Beech Fern**
**Phegopteris hexagonoptera**

**Blue Cohosh**
**Caulophyllum thalictroides**

**Bloodroot**
**Sanguinaria canadensis**

**Trillium rugelii**

**Allegheny Spurge**
**Pachysandra procumbens**

**Figure 9**. Indicator Species: Mafic Terrain pH 6.5-7.0+

**Soil pH as a Proxy for Substrate Lithology**

pH is the negative logarithm of the $H^+$ ion concentration in soils on a scale of 1 to 14. Another way to express pH is the relative proportions of $H^+$ and $OH^-$ ions in soils. Soils with a pH range of 1 to 6.99 are acidic, those with a pH of 7.01 to 14 are alkaline, and those with a pH of 7 are neutral. The pH of soils in the Carolinas ranges from ~4.5 to 7.2, with values above 7.2 only around marble outcrops and shell middens.

Soil pH is determined by the chemical composition of substrate lithology, substrate weathering, hydrology, the activities of soil micro-organisms and fungi, resident plants and animals, climate conditions, and site history. Foremost in soil pH formation is the relative quantity of acidic metals (primarily Al and Si) and alkaline metals (Ca, Mg, Na, K, and Mn) in the parent rock. Acidic cations such as $Al^{+3}$ readily exchange with $H^+$ ions in the soil solution and act to increase $H^+$ concentration and acidity. Alkaline cations such as $Ca^{+2}$ attract $OH^-$ ions and raise alkalinity. When there is a balance in acidic and alkaline metals in a lithologic unit, the resultant soil pH will be circum-neutral. Imbalance will produce either acidic or alkaline soil. In Table 2, a whole rock analysis highlights the differences between the two major rock types with regard to the ratios of key pH affecting metals Al, Mg, and Ca

**Table 2**. Results of whole rock analysis for felsic and mafic rock types

| Unit | SiO2 | Al2O3 | Fe2O3 | MgO | CaO | Na2O | K2O | TiO2 |
|---|---|---|---|---|---|---|---|---|
| Table Rock gneiss | 76.06 | **12.76** | 1.1 | **0.11** | **0.52** | 2.62 | 5.49 | 0.13 |
| Poor Mt. amphibolite | 47.4 | **16.42** | 11.02 | **7.58** | **10.24** | 3.18 | 0.36 | 1.31 |

Since weathering progresses in stages, different layers in a soil profile can have a different pH. These differences are summarized in Table 3. Because of the activities of soil micro-organisms, a mature A horizon contains the most exchangeable cations for affecting pH and providing plant nutrients. B horizon soils typically have a lower pH.

In mature habitats with either mafic or felsic substrates, A horizon soils are dark gray to black colored and thick due to the high concentration of humus. An A horizon soil with a mafic substrate will have a soil pH of 6.4 to 7.2 depending on the amount and composition of mafic minerals. The pH of B horizon soil will be in the range of 5.8 to 6.0. In a felsic terrane, A horizon soils will have a pH of 4.8 to 5.1 depending on the proportions of feldspar, quartz, and micas. The B horizon pH will be only slightly different. The presence of epidote in felsic rocks will increase soil pH by a few tenths.

In a disturbed area where the A horizon is essentially absent, surface pH will be substantially lower above mafic rocks (~5.5). This occurs because basic cations are bound to clays and colloids and there is a paucity of soil micro-organisms. The soil micro-organisms are the agents responsible for releasing ions from the mineral matrix. In disturbed felsic terranes, surface pH will be similar to mature A horizon pH.

Soil texture and color are also correlated with substrate lithology in disturbed areas. B horizon surface soils above mafic rocks will typically be dominated by dense red clay with sparse quartz sand. B horizon surface soils above felsic rock will be sandy and light to medium tan or reddish.

Occasionally, soil characteristics and plant specialist occurrences do not correlate with nearby outcrops. These anomalies likely indicate the presence of a nearby lithologic boundary, rock units with variable mineralogy, discrete pods or layer, or where ions have migrated downslope or persist from overlying rocks that have been removed by erosion or man.

**Table 3**: Differences in soil pH as a function of horizon integrity

| Substrate | Soil Horizon | pH | Color |
|---|---|---|---|
| Felsic | Mature A horizon | 4.8-5.1 | dark gray to black and humus rich |
| | B horizon pH below mature A horizon | 4.8-5.1 | medium tan to reddish and sandy |
| | B horizon pH with absent A horizon | 4.8-5.1 | light to light reddish and sandy |
| Mafic | Mature A horizon pH | 6.4-7.2 | dark gray to black and humus rich |
| | B horizon below mature A horizon | 5.8-6.0 | red clay dominant |
| | B horizon pH with absent A horizon | ~5.5 | red clay dominant |
| Intermediate | Mature A horizon pH | 5.7-6.3 | dark gray to black and humus rich |
| | B horizon below mature A horizon | 5.3-5.7 | depends on biotite content |
| | B horizon with absent A horizon | 5.2-5.6 | depends on biotite content |

**Soil Analysis Transect**

A 1400 meter long soil analysis transect was conducted on the northwest side of Wadakoe Mountain. Samples of the A soil horizon were collected at approximate intervals of 200 meters. As depicted on the map in Figure 10, the transect began in the Henderson Gneiss, crossed the Eastatoee Fault into the Chauga River Formation, and ended below the summit of Wadakoe Mountain in the Poor Mountain amphibolite. The graph in Figure 11 shows significant changes in pH, base saturation, and Al, Ca, and Mg concentrations.

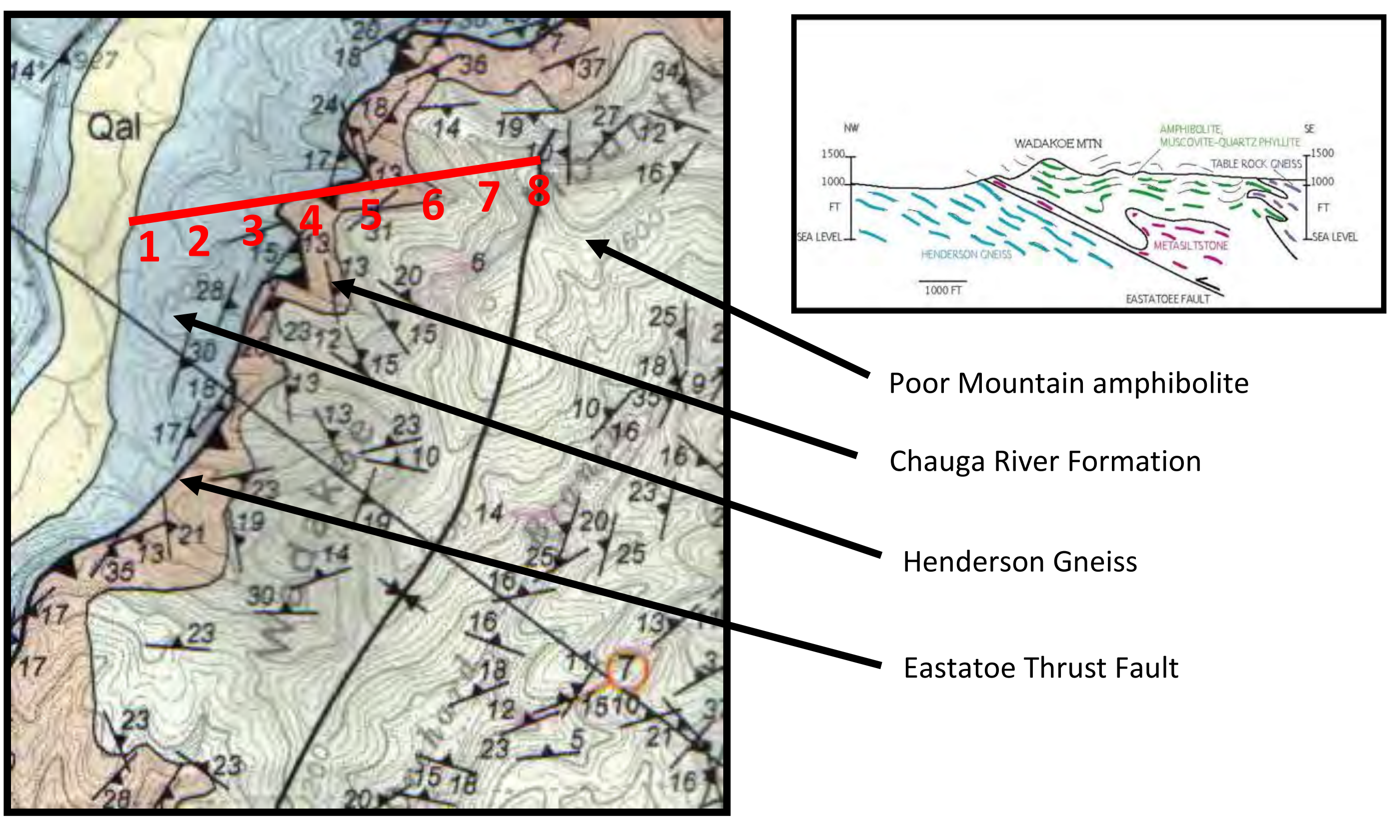


**Figure 10**. Traverse across the northwest side of Wadakoe Mountain

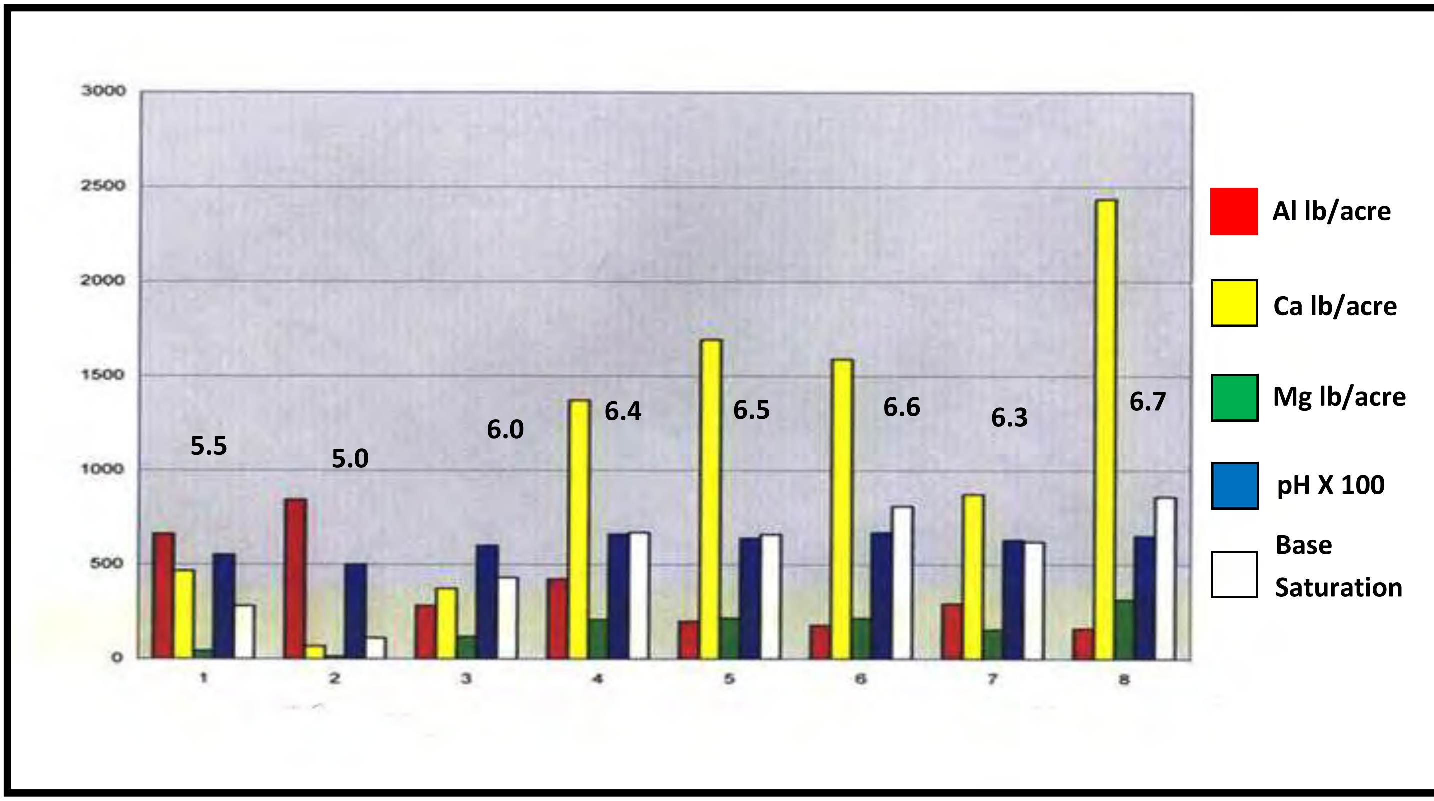


**Figure 11**. Soil analyses for samples collected along the northwest side of Wadakoe Mountain, the pH values are shown above each sample

**Definitions: Community Connections**

**Physical Connections:** Places and objects exist where community members reside, or members push other members aside for space. Solutions transport ions, molecules, micro-organisms, silt, and clastics from place to place. Regional climate and local topography create mega-, meso– and micro-communities depending on slope, aspect, hydrology, elevation, latitude, and rock outcrops.

**Consumption, Parasitism, Decomposition, and Excretion:** Some members consume other living, dead, or inorganic members totally or in part and excrete portions that are not needed. When organisms decompose, DNA molecules are resistant to decomposition and may persist in a community for thousands of years.

**Symbiosis:** Partnerships exist where two or more members support each other, as examples, through endodermic and exodermic mutualism, in reproduction processes, and in defense against pathogens.

**Chemical Connections:** Members react with each other to produce different members during hydration, hydrolysis, carbonation, oxidation, reduction, dissolution, and complexation (organic acid reactions with minerals).

**Organic Production:** Living things absorb community components for synthesizing DNA, RNA, tissue, hormones, antigens, antibodies, metabolites, food, gametes, etc.

**Cation and Anion Exchange:** Some community members, such as clays, colloids, humus, and living organisms have surface or interstitial positive or negative charges that attract ions. Depending on the strength of ion attachment and the relative number of different ions in the community, ion exchanges occur where one ion replaces another ion that is then free to make another connection elsewhere.

**Substrate Geology:** Many community members have strong connections with the chemistry of substrate mineralogy. Organisms connect directly as epipetric (on and near the surface) and endopetric (in solid rock interstices hundreds of meters below the surface) and with the weathering products of rocks.

**Disturbance:** Events of fire, floods, the introduction and effects of invasive organisms, the loss of community participants, geophysical events, climate change, and human modification degrade communities and their connections. However, for example, some prairie and forest species are dependent on fire that historically occurred periodically.

## Geology of the Eastatoe Gap and the northern Sunset quadrangles, Pickens and Greenville counties, South Carolina

### Introduction and Regional Geologic Relationships

The Eastatoe Gap and the Sunset 7.5-minute quadrangles lie in the Tuguloo terrane of the Inner Piedmont (Figure 12, 13). The regional structural framework of northwest South Carolina and adjacent North Carolina southeast of the Brevard fault zone is described in terms of overlapping, northwest to southwest-emplaced thrust sheets (Griffin, 1978, and references therein; Hatcher, 1993 and references therein; Nelson and others, 1998; Hatcher and Merschat, 2006). Each thrust sheet involves deformation of Neoproterozoic-Middle Paleozoic-age greenschist- or amphibolite-grade metasedimentary and meta-igneous rocks. Between Oconee and Greenville Counties, South Carolina, and in nearby Henderson and Transylvania Counties, North Carolina, the thrust stack sequence (northwest to southeast) was originally referred to as the mostly non-migmatitic Chauga belt, the migmatitic Walhalla nappe, the Six Mile thrust sheet, the Star nappe, and the Antreville nappe (Griffin, 1969, 1971, 1974a, 1974b).

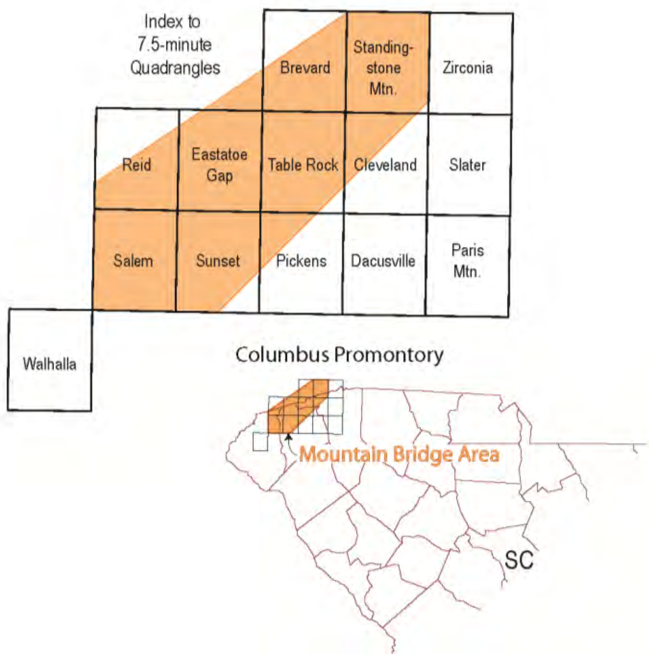


**Figure 12**. Index map of quadrangles, Mountain Bridge Area.

Lithostratigraphic units within the Chauga belt include: Chauga River Formation (Cambrian to Lower Ordovician) button schist, metasiltstone, and metasandstone; Poor Mountain Formation (Middle Ordovician) amphibolite, schist, and metaquartzite; and Henderson Gneiss (Early Ordovician) (Hatcher, 2002). As a result of polyphase folding, the individual thickness of each unit is unknown. The Henderson Gneiss also has a variably developed mylonitic fabric that preserves microcline augen of different shapes and dimensions (Davis, 1993). Present throughout the Henderson are sigma and delta porphyroclasts, and S-C shear sense indicators. Recurrent ductile, dextral strike slip faulting along the Brevard fault zone accompanied by high grade metamorphic conditions occurred in the Neoacadian (Late Devonian-Mississippian) and Early Alleghanian (325 Ma) (Merschat and Hatcher, 2007).

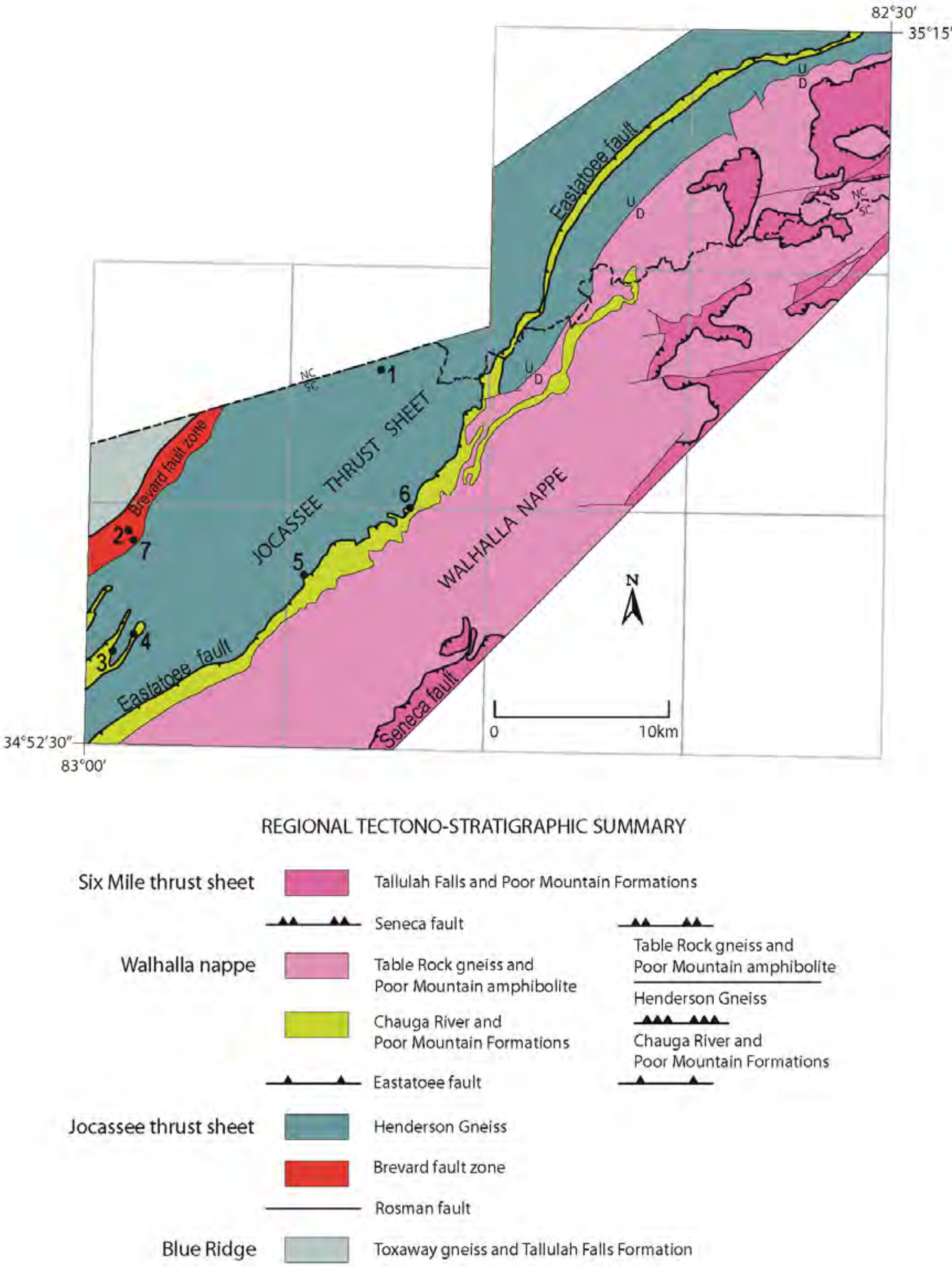


**Figure 13**. Regional tectono-stratigraphic summary, northwestern South Carolina and adjacent North Carolina.

Recent geologic mapping in the Eastatoe Gap and Sunset quadrangles (Garihan 2005; Garihan and others, 2005) divides the western Inner Piedmont thrust stack into (northwest to southeast) the Jocassee, Walhalla, and Six Mile thrust sheets. Individual formations that are present on each thrust sheet are given in Figure 13. The ductile Eastatoee fault (Garihan and Clendenin, 2007) and the Seneca fault (Garihan, 2001 and references therein) lie, respectively, at the base of the Walhalla nappe and the base of the structurally higher Six Mile thrust sheet. Observations show that the Eastatoee fault is marked by a deformation style similar to the Seneca fault at the base of the Six Mile thrust sheet (Figure 13). That is, progressive ductile deformation along both resulted in grain size reduction, shearing, and flattening fabrics. Those similarities led to the recognition that the Eastatoee fault is another of the major ductile structures that assembled the Western Inner Piedmont. In Sunset quadrangle the Eastatoee fault is exposed at Dug Mountain (Figure 14; location 5 on Figure 13), Horse Mountain (Figure 15), and along Rt. 178 south of Beasley Gap (Figure 16).

The identification of the Eastatoee fault expands the spatial distribution and lithostratigraphic character of the Walhalla nappe. Identification re-assigns the Chauga River Formation rocks of the Chauga belt above the fault to the Walhalla nappe. Hence the Walhalla nappe encompasses the thrusted rock package between the Eastatoee fault at its base and the overlying Seneca fault marking the base of Six Mile thrust sheet. The Jocassee thrust sheet is underlain by Henderson Gneiss here and in the Salem and Reid quadrangles. Excellent exposures of the Eastatoee fault there are found along the shores of Lake Jocassee (geologic map of Clendenin and Garihan, 2007) (Figure 17).

**Figure 14.** Fault contact between saprolitic gray Henderson Gneiss (gray) and Chauga River Formation (darker schist and metasiltstone) shown by pencil. West flank of Dug Mountain, northwest Sunset quadrangle.

**Figure 15**. The Eastatoee fault places micaceous metasiltstone of the Chauga River Formation (brown) over Henderson Gneiss ultramylonite (gray). Northwest flank of Horse Mountain, above Reedy Cove, Eastatoee Gap quadrangle. View to the south.

**Figure 16**. The Eastatoee fault exposed along Rt. 178, south edge of Eastatoe Gap quadrangle. Hammer (handle 40 cm) lies on fault.  Grain size-reduced Henderson Gneiss below and Chauga River Formation schistose metasiltstone above fault. View to northeast.

**Figure 17**. Button schist of Chauga River Formation (left) is thrust over grain-size reduced Henderson Gneiss along the Eastatoee fault (at hammer), southwest bank of Lake Jocassee (Horsepasture River) in Oconee County, Reid quadrangle, South Carolina. UTM section 17, 3878210 m N, 323950 m E (1927 NAD). View to west.

## Description of the Rock Units

### *Walhalla Thrust Sheet*

Poor Mountain Formation amphibolite. (Middle Ordovician)

Resistant amphibolite and minor interlayered metasiltstone, schist, and garnet-muscovite-quartz phyllonite occur in a belt of variable width from Lake Keowee (southwest Sunset quadrangle) to the southeast flank of Horse Mountain (southeast Eastatoe Gap quadrangle). Excellent exposures of amphibolite occur on Wadakoe Mountain and along Peach Orchard Branch on its southeast flank. Amphibolite occurs at Wadakoe Mountain (1,865 ft elev.) and in the area between Peach Orchard Branch and Winnie Branch, where the amphibolite exposure belt is at its widest (Garihan, 2003). Petrography indicates that amphibolites near Wadakoe Mountain were metamorphosed to the epidote amphibolite facies of metamorphism (Prince and Ranson, 2004). Contacts with Table Rock gneiss are sharp, whether intrusive and modified by folding or faulted.

Amphibolite is mafic, fine-crystalline, and thinly layered with leucocratic, fine- to coarse-crystalline pods and layers of quartz and feldspar parallel to foliation. Thin interlayers (a few centimeters thick) in amphibolite are composed of green, fine-crystalline, granoblastic feldspar, epidote, and quartz. Polyphase folding is observed in mesoscopic exposures. The map unit includes minor muscovite-biotite "button" schist. (The bent, tapered ends of lenses of mica in the schist produced by ductile deformation resemble "buttons" when weathered out of the rock onto the surface.) The Poor Mountain Formation amphibolite map unit also includes garnet-muscovite-quartz phyllonite, quartz-muscovite metasandstone, clinoamphibole schist, and garnet-hornblende gneiss. Chemical weathering of amphibolite forms a distinctive, limonite-rich rock, or it produces float with limonite rinds on fresher amphibolite cores.

Chauga River Formation metasiltstone and garnet schist. (Cambrian-Early Ordovician)

Metasiltstone and schist constitute a thin, continuous belt of resistant rocks that crosses the quadrangles from Lake Keowee to Sharp Top Mountain (Sunset quadrangle), and from Beasley Gap to White Oak Mountain (Eastatoe Gap quadrangle). Ductile deformation features, folds, and boudinage are common in these cliff-forming rocks. Foliation in Chauga River Formation rocks is dominantly a secondary, transposition foliation (Figure 18).

Two end-member lithologies make up a range of compositional variation in this metapelitic map unit. Metasiltstone is dark gray, fine-crystalline, poorly layered, well foliated, locally schistose garnet-muscovite-biotite-porphyroclastic feldspar-quartz gneiss. With increased mica this lithology becomes a dark brown, fine- to medium-crystalline, garnet-muscovite-biotite "button" schist. Almandine garnet (1-5 mm) is idioblastic. Coarse muscovite flakes or aggregates of finer muscovite in the schist form conspicuous "fish" (lozenge-shaped bundles), in a groundmass of black, aligned, fine-crystalline biotite. Schistose rocks locally contain resistant layers and pods of medium- to coarse-crystalline granitoid material and pegmatite, locally foliated (sheared). The schist displays S-C fabric. Also present are finely laminated muscovite-quartz metasiltstone, biotite-quartz metasiltstone, mica metaquartzite, and minor amphibolite.

In southeastern Eastatoe Gap quadrangle, sillimanite-garnet-mica gneiss is locally encountered within presumably epidote amphibolite facies rocks of the Poor Mountain Formation. The index mineral sillimanite is indicative of a higher metamorphic grade. This sillimanite-garnet-mica gneiss lies near the regional contact with Table Rock gneiss. The sillimanite may be due to higher temperature effects of the adjacent large intrusive body of synkinematic granite.

**Figure 18**. Lenticular boudin of epidote hornblende gneiss enveloped by "button schist", Chauga River Formation, Horse Mountain. Tightly folded internal compositional layering of the boudin is truncated by a surrounding transposition (secondary) schistosity. View to southeast.

Table Rock gneiss. (Middle Ordovician)

A suite of felsic, granitic rocks and related intrusional phases (both syn- and post-kinematic) with mafic rocks underlies the middle one-third of Sunset quadrangle (Garihan, 2005), extending as a series of prominent rocky balds and rugged peaks northeastward into the Table Rock quadrangle (Garihan and Ranson, 2003) (Figure 12).

The main lithology of the Table Rock gneiss is a biotite quartzo-feldspathic gneiss, which locally is leucocratic. The gneiss is gray to tan, fine- to medium-crystalline, and moderately well layered compositionally. Foliation is defined by aligned micas or discontinuous, lenticular aggregates of quartz and feldspar. Sheared varieties of quartzo-feldspathic gneiss contain quartz ribbons a few millimeters thick defining foliation or muscovite, due to K-feldspar breakdown during ductile deformation. A well-developed mineral lineation occurs on foliation surfaces in many places.

The Table Rock gneiss map unit also includes muscovite-biotite-quartz-feldspar gneiss, micaceous biotite gneiss, biotite-feldspar augen gneiss, hornblende-quartz-feldspar gneiss, poorly layered, poorly foliated, biotite granitoid gneiss, and aplite, pegmatite with local biotite selvedges, and quartz veins. Mafic rocks are layered amphibolite, biotite amphibolite, hornblende gneiss, and schist.

### *Jocassee Thrust Sheet*

Henderson Gneiss. (Early-Middle Ordovician)

Henderson Gneiss is part of a large regional igneous body that commonly shows distinctive large feldspar crystals (< 5 cm) in a finer quartz, feldspar, and mica matrix. The gneiss is exposed in the areas flanking Eastatoe Creek in Sunset quadrangle. All major peaks above Rocky Bottom, South Carolina (Figure 19), at the headwaters of Eastatoe Creek have impressive balds formed on Henderson Gneiss.

Biotite-microcline augen gneiss (granodiorite to granite in composition) is gray to dark gray and fine- to coarse-crystalline. The gneiss generally is well foliated. Compositional layering includes discontinuous mafic layers and lenticular aggregates of quartz and feldspar. Conspicuous pink, porphyroclastic microcline (0.5 to 5 cm) has white myrmekite rims. Owing to its coarser, feldspathic character, Henderson Gneiss is somewhat less resistant to weathering than the more quartzose Table Rock gneiss. Mylonitic fabric development is variable: protomylonite in sheared pegmatite, mylonite, and thinly layered ultramylonite in proximity to ductile faults and high strain zones. Highly sheared varieties of Henderson Gneiss contain either 1) quartz or microcline ribbons, or 2) recrystallized, fine-crystalline muscovite. On the outcrop scale, S-C fabric and strain partitioning (alternation of zones with differences in strained fabric) are present. Henderson Gneiss L-tectonites display excellent mica and quartz-feldspar mineral lineations on foliation planes.

In many outcrops the Henderson Gneiss is a light gray, locally leucocratic, layered biotite augen gneiss. Sheared textures (Figure 20) indicate that homogeneous ductile deformation has produced a strongly layered rock from the originally heterogeneous granitoid. The presence of ultramylonitic Henderson Gneiss also indicates progressive ductile deformation. Biotite-augen gneiss is interlayered with resistant, light-gray, leucocratic, fine- to medium-crystalline, muscovite-quartz-feldspar gneiss; quartz-feldspar gneiss; fine- to medium-crystalline, biotite quarto-feldspathic gneiss; aplite, pegmatite, and quartz veins; and minor biotite amphibole gneiss.

**Figure 19**. Roundtop. Northwest flank of Roundtop Mountain, above Rocky Bottom, South Carolina. View to the east across mountainous topography (~1700 feet relief) and scattered balds underlain by Henderson Gneiss.

**Figure 20**. S-C-C' structure in mylonitic Henderson Gneiss, Twisted Pine Mountain, south-central Eastatoe Gap quadrangle. Horizontal surfaces are C (shear) surfaces indicating pervasive movement planes. Individual tapered microcline porphyroclasts with asymmetric tails of fine quartz and feldspar on upper left and lower right margins (sigma structures) indicate top to left (northwest) shearing. Pencil is parallel to C' surfaces (upper right to lower left) warping the C surfaces. Geometry of C' surfaces indicates top is down and to the left, consistent with SW-directional extensional movements. Structures developed during regional Neoacadian deformation (Late Devonian-Mississippian).

## Geology and Plant Connections at Field Trip Stops

### Geology of the Chimneytop-State line Area along SC Hwy 178 (Paw Paw Creek)

The dominant rock type in central Eastatoe Gap quadrangle south of the South Carolina state line is Henderson gneiss (Figure 21). In the Paw Paw Creek area near the headwaters of Eastatoe Creek it intrudes irregular, mappable bodies of biotite amphibolite, biotite-hornblende gneiss (< 50 modal per cent mafic minerals), mafic biotite gneiss, and minor biotite-hornblende metagabbro. Complex interfingering and interlayering relationships of the mafic rocks and Henderson Gneiss are visible in scattered exposures. Contacts are sharp (Figure 22) and interpreted as intrusive. The affinity of the mafic rocks is unknown.

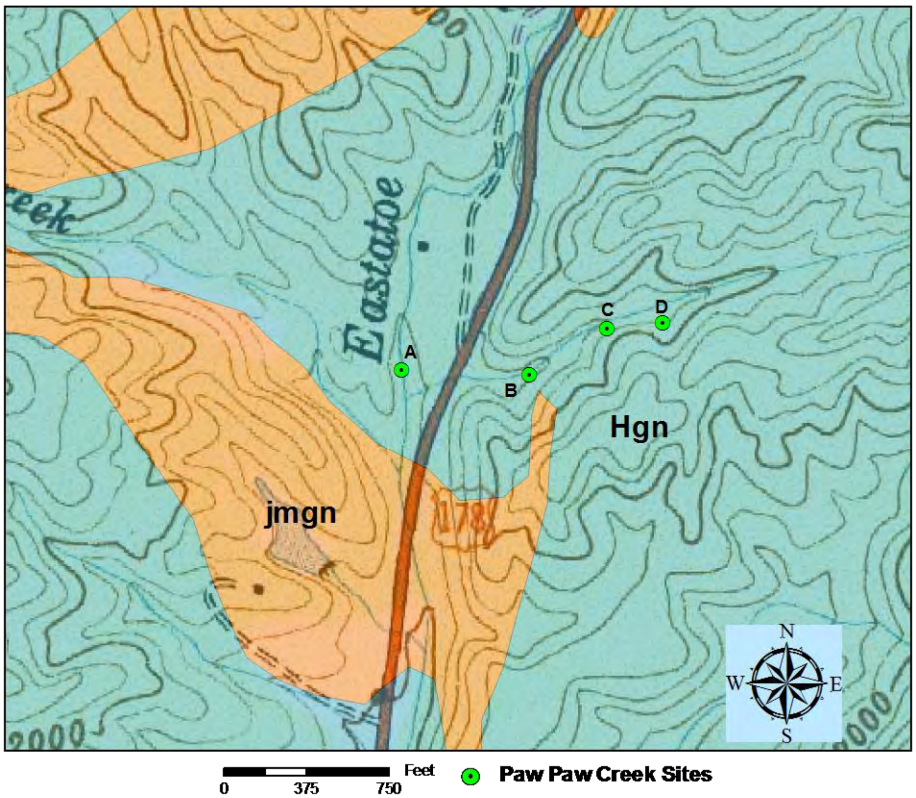


**Figure 21**. Geologic map of the Paw Paw Creek area, Eastatoe Gap quadrangle. Map labels: Hgn- Henderson Gneiss; jmgn- mafic gneiss and amphibolite.

### Plant Connections at Paw Paw Creek

Paw Paw Creek was chosen as the starting point for this field trip as it showcases the use of plants as indicators of geologic units where outcrops are absent or misleading. This cove is much more floristically diverse than any other cove along this stretch of highway. Immediately adjacent to the road are outcrops of Henderson Gneiss (Hgn), but a few feet off the road Shape-lobed Hepatica, Broad Beech Fern, and Silvery Glade Fern can be found growing. These plants are indicators of higher soil pH not typically associated with the dominant felsic substrate (Hgn).

In the cove, outcrops of Hgn are present on the slopes and along the creek with acidophiles like Mountain Laurel, Rhododendron, and Northern Hemlock scattered throughout. But the

plant community also includes large numbers of transition plants and indicators of mafic rock such as Paw Paw trees, Spice Bush, Hepatica, Blue Cohosh, Yellow Buckeye, Northern Maidenhair Fern, Silvery Glade Fern and Broad Beech Fern. Even more telling is the presence of a large patch of Narrow Glade Ferns that are not observed growing in any soil with a pH less than 7. A pH test beside the fern patch registered 7.0 indicating the nearby presence of mafic rock.

A detailed survey of the plants, outcrops, and soil pH in the cove and surrounding area indicates the presence of amphibolite. The amphibolite probably occurs as large fragmented body in the form of discrete pods and discontinuous layers within the Henderson Gneiss. Transects across the cove showed areas of mixed plant indicator specialists, areas of homogeneous specialists, and transition zones where mafic indicator plants were replaced by felsic indicator plants. An outcrop (marked D in Figure 21) exposes a contact between the Henderson Gneiss and an underlying mafic rock layer.

**Figure 22** . Interlayered coffee grounds-weathering mafic biotite gneiss saprolite and fine-crystalline Henderson Gneiss, Wild Hog Creek Creek (< 1 km south of state line). Henderson Gneiss (augen <0.5-1 cm) intrudes thinly layered biotite gneiss. View to northwest.

**Geology of the Beasley Gap Area**

Chauga River Formation rocks and Poor Mountain Formation amphibolite in southeast Eastatoe Gap quadrangle in the Beasley Gap-Horse Mountain area are thrust over Henderson Gneiss along the Eastatoee Fault (Figure 23). Parallel to the Eastatoee is a northeast-striking brittle fault with reverse motion that displaces it (Figure 24). A third set of faults with northwest strikes offsets the two northeast-striking faults.

Intrusive and structural relationships in southeast Eastatoe Gap quadrangle suggest a complex geologic history. Map patterns of the Chauga River, Poor Mountain, and Table Rock units indicate polyphase folding and intrusion. In general, the initial regional development of

folds in Chauga River and Poor Mountain rocks was interrupted by the intrusion of a large granitic body of the Mid-Ordovician Table Rock Plutonic Suite (Ranson and others, 1999). The irregular Table Rock intrusive contacts are discordant to the formation contact between the Chauga River and Poor Mountain rocks. Subsequently the Table Rock and earlier folds in the two formations were tightly flattened into a system of northeast-trending, northwest-vergent isoclines and subjected to high-grade metamorphic conditions. Regional structural relationships, southwest-directed sheath folds, and gently plunging stretching lineations of northeast and southwest trends in the area suggest this took place in the Neoacadian (late Devonian to Mississippian) (Hatcher and Merschat, 2006). Transposition schistosity in the Chauga River rocks (Figure 18) presumably dates from this deformational episode. Southeast of Beasley Gap, a possible klippe of Six Mile thrust sheet rocks is mapped lying above Chauga River and Poor Mountain rocks (Garihan and others, 2005). The rocks were broadly folded along easterly trends subsequent to the development of the isoclines.

At Beasley Gap the Eastatoee fault is not exposed, but the contact position is easily determined. The textural characteristics of the Henderson Gneiss and the Chauga River garnet schist are well exposed at this location.

**Plant Connections at Beasley Gap**

The proximity to a fault zone boundary where an over-thrusted mafic body has been removed by erosion down to the underlying Hendersonville Gneiss creates a transition zone where the occurrence of plant specialist and soil pH will be affected accordingly.

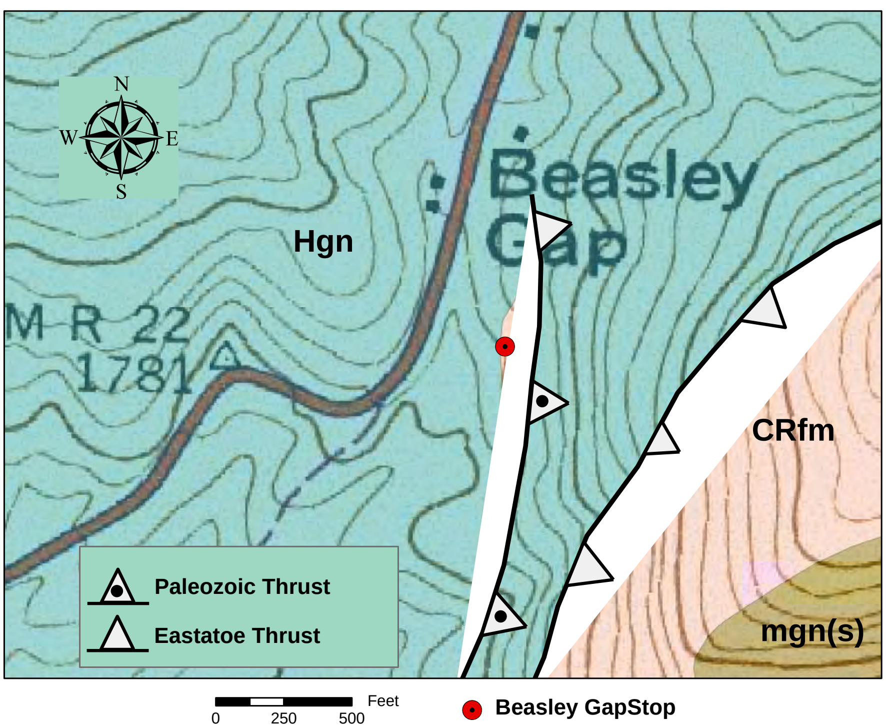


**Figure 23**. Geologic map of the Beasley Gap area, southeast Eastatoee Gap quadrangle. Map labels: HGN- Henderson Gneiss; CRfm- Chauga River Formation; mgn(s)- mica and hornblende gneisses and schists.

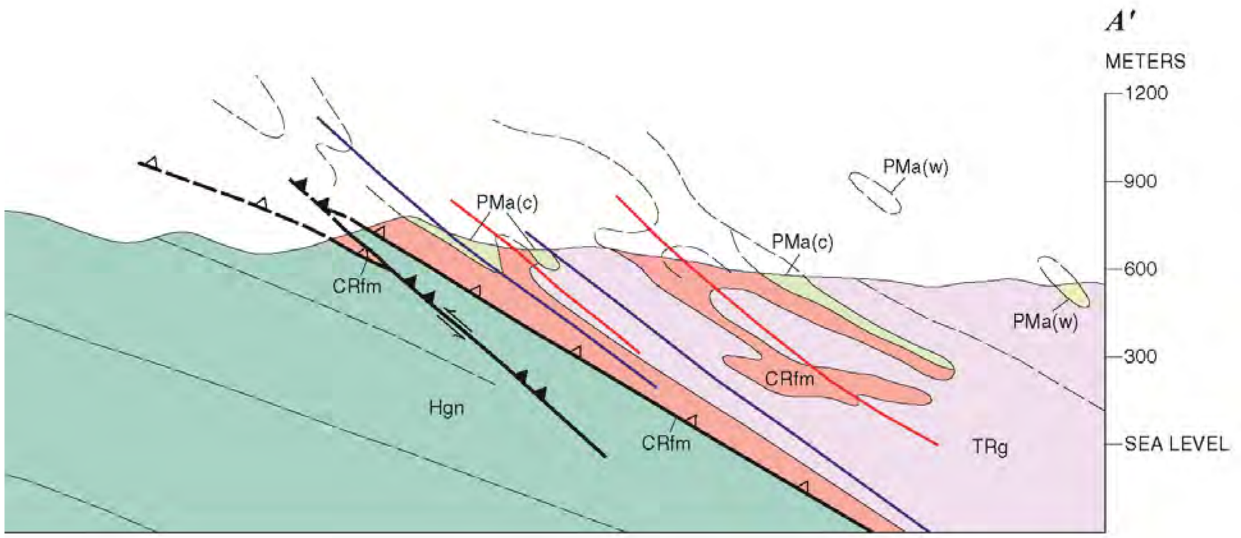


**Figure 24**. Cross section through Horse Mountain, southeast Eastatoe Gap quadrangle. Map labels: Hgn- Henderson Gneiss; CRfm- Chauga River Formation; PMa(c), PMa(w)- Poor Mountain Formation; TRg- Table Rock gneiss; mgn(s)- mica and hornblende gneisses and schists.

**Geology of the Wadakoe-Cove Gap Region**

Excellent exposures of rocks of the Chauga River and Poor Mountain Formations occur in northwest Sunset quadrangle in the Wadakoe Mountain-Cove Gap region (Figure 25). Amphibolite and lesser garnet-muscovite-quartz phyllonite occur at the peak of Wadakoe Mountain (1,865 ft elev.) and along Peach Orchard Branch on its southeast flank. The amphibolite exposure belt is at its widest, about 2 km, between the latter and Winnie Branch (Garihan, 2003). Wadakoe Mountain is centered in the core of a large synform of Poor Mountain amphibolite. An open, north-trending antiform underlies Cove Gap. Structural relationships of the rock units and the associated folds, and the Eastatoee fault are shown in the cross section (Figure 26).

An intrusive contact between the Poor Mountain Formation and Table Rock gneiss occurs in the vicinity of Clearwater Branch (Figure 25). Along strike to the southwest, the irregular intrusive contact has been truncated by a southeast-dipping reverse fault that parallels the Eastatoee fault. The fault has been interpreted as an out-of-the-core thrust related to regional northwest-vergent, overturned folding in the Walhalla nappe. The intrusion-thrust relationships are shown on Figure 26.

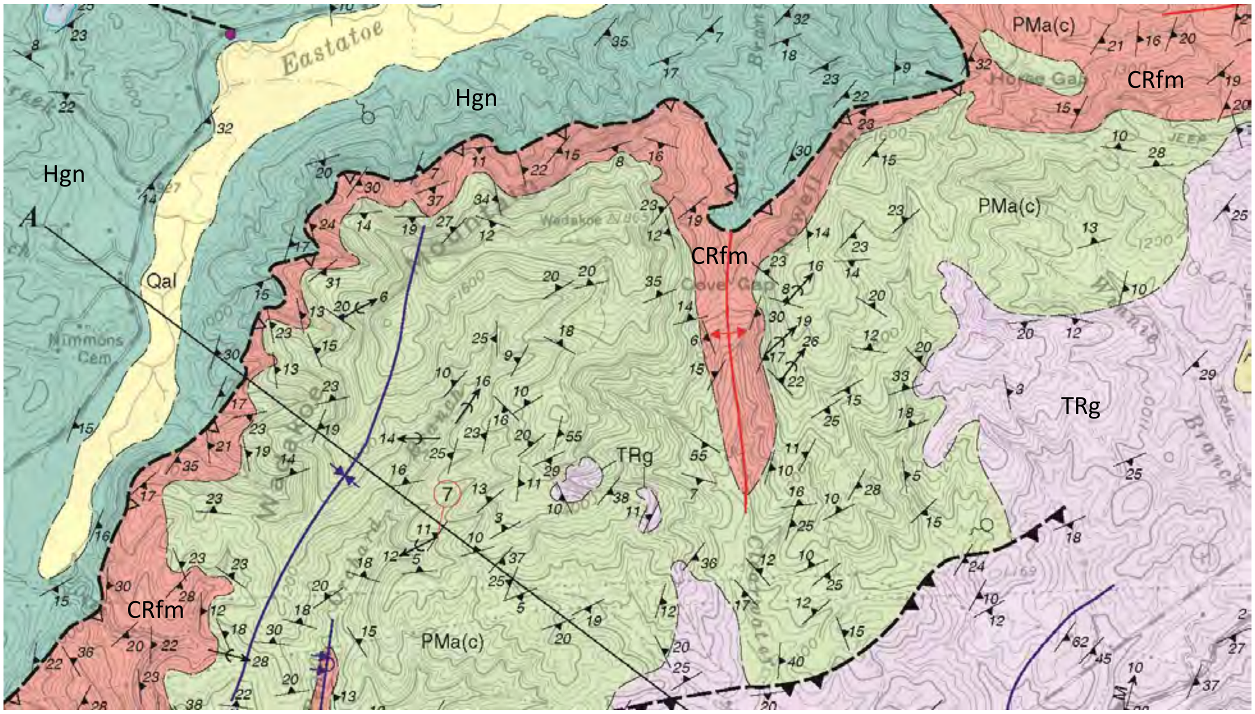


**Figure 25**. Geologic map of the Wadakoe Mountain-Cove Gap area, northwest Sunset quadrangle. HGN- Henderson Gneiss; CRfm- Chauga River Formation; PMa(c)- Poor Mountain Formation; TRg- Table Rock gneiss;

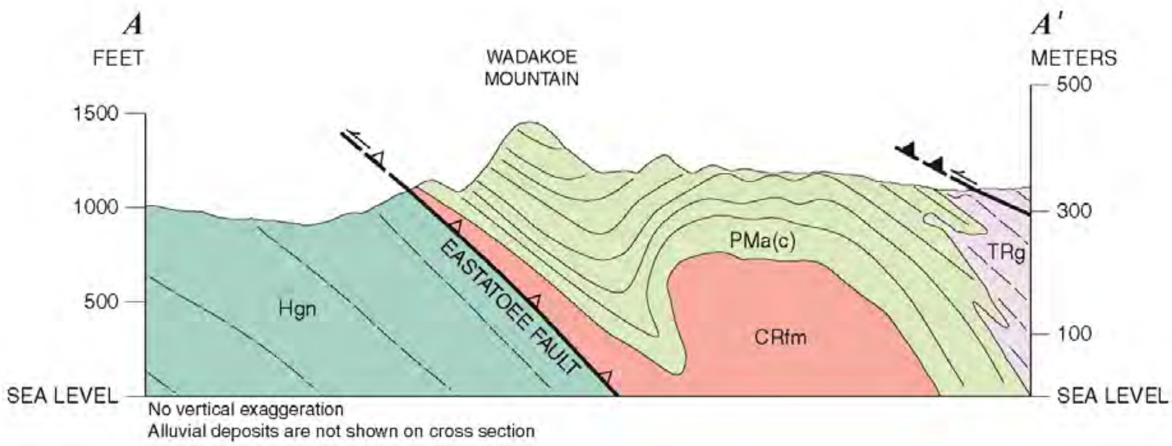


**Figure 26**. Cross section through Wadakoe Mountain, northwest Sunset quadrangle.

**Plant Connections at Cove Gap**

The dirt road from SC Highway 11 to Cove Gap is underlain mostly by Table Rock Gneiss. A few hundred yards before reaching Cove Gap the Poor Mountain amphibolite is encountered. Most of the land before on the road up to Cove Gap was farmed to exhaustion many years ago. The A horizon soils are absent so the surface is largely B horizon with a paucity of humus and a diminished soil micro-organism community. The soil pH of these B horizons is around 5.5 above the amphibolite and ~5.0 above the Table Rock gneiss. Accordingly, the plants above

both substrates are acidophiles. Acidophiles grow above amphibolite in this situation because the calcium and magnesium ions are strongly bound to clay crystals and colloids in the B horizon and are not available. While pH can still be used to indicate substrate lithology, the gap is about 0.5 of a pH point. The pH of mature A horizon soils is typically 6.5 to 7.0 for the amphibolite and 4.8 to 5.1 for the Table Rock gneiss, a difference of 1.5 pH points.

At Cove Gap, the topography becomes steeper and rockier and thus the land was not farmed. The bottom of the cove is underlain by the Chauga River "button schist," and slopes on either side are underlain by Poor Mountain amphibolite. The A horizon soils in the cove are intact and dark gray to black with high micro-organism and humus content, except along the old logging road path where the A horizon was removed. The floristic diversity in the cove is one of the highest in the Carolinas, because the soils are rich and circum-neutral. Many calciphile plant specialists and cosmopolitans are present. Acidophiles are absent.

**Long Shoal Wayside Park**

Extensive pavement exposures of Table Rock gneiss are present at Long Shoals Wayside Park along Little Eastatoe Creek, ~0.75 km northwest of Buzzard Roost Mountain. The small Park is along Rt. 11 east of Lake Keowee. The biotite quartzo-feldspathic gneiss has abundant compositional layers of coarse quartz-feldspar pegmatite lying parallel to gneissic foliation (Figure 27). Numerous interesting features are spectacularly exposed along the creek (Figure 28), including several sets of systematic joints and potholes. Rounded bedrock exposures have been extensively polished, fluted, (Figure 29) and grooved potholes appear to have formed along prominent joint directions by current scouring action along these rock weakness planes (Figure 30).


**Figure 27**. Table Rock gneiss and pegmatite.

**Figure 28**. Pavement exposures of Table Rock gneiss along Little Eastatoe Creek.

**Figure 29**. Pits, flutes, and grooves on polished bedrock surfaces produced by current action during high velocity, high discharge stream flow. Reflective surfaces face in the upstream direction. Lens cap 5.7 cm.

**Figure 30**. Potholes developed along joints.

## Plant Connections at Long Shoals and Poe Creek

All of the substrate at these two sites is Table Rock Gneiss. This would indicate that the pH should be accordingly low and plant communities dominated by acidophiles.

The flood plain of Poe Creek has almost no rock outcrops, although there are outcrops on road cuts nearby. The flood plain contains at least six fern species specialists.

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## Field Trip Stops

The locations of the field trip stops are shown in Figure 31. In Figure 32 the locations are associated with their respective geologic units and features.

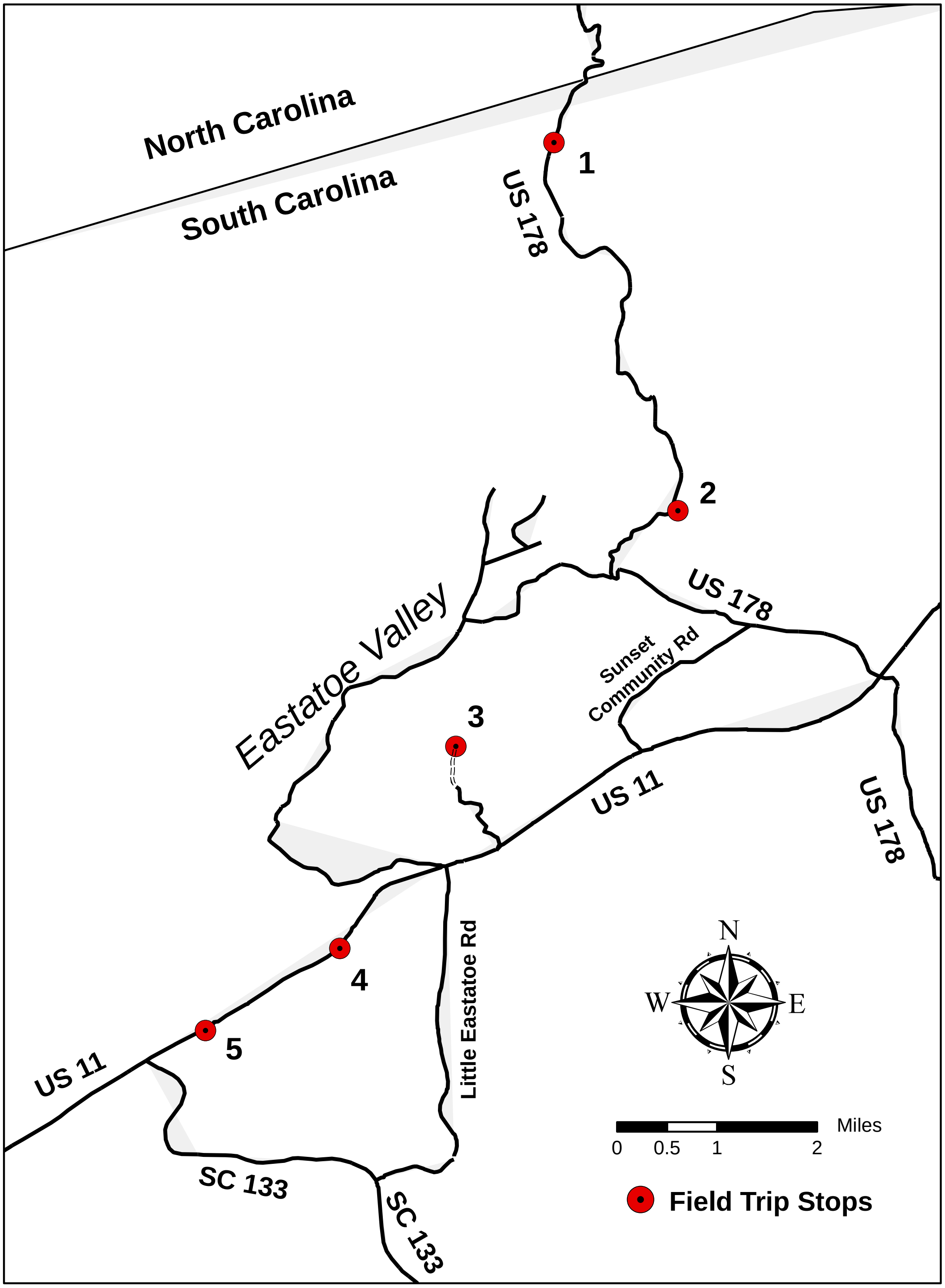
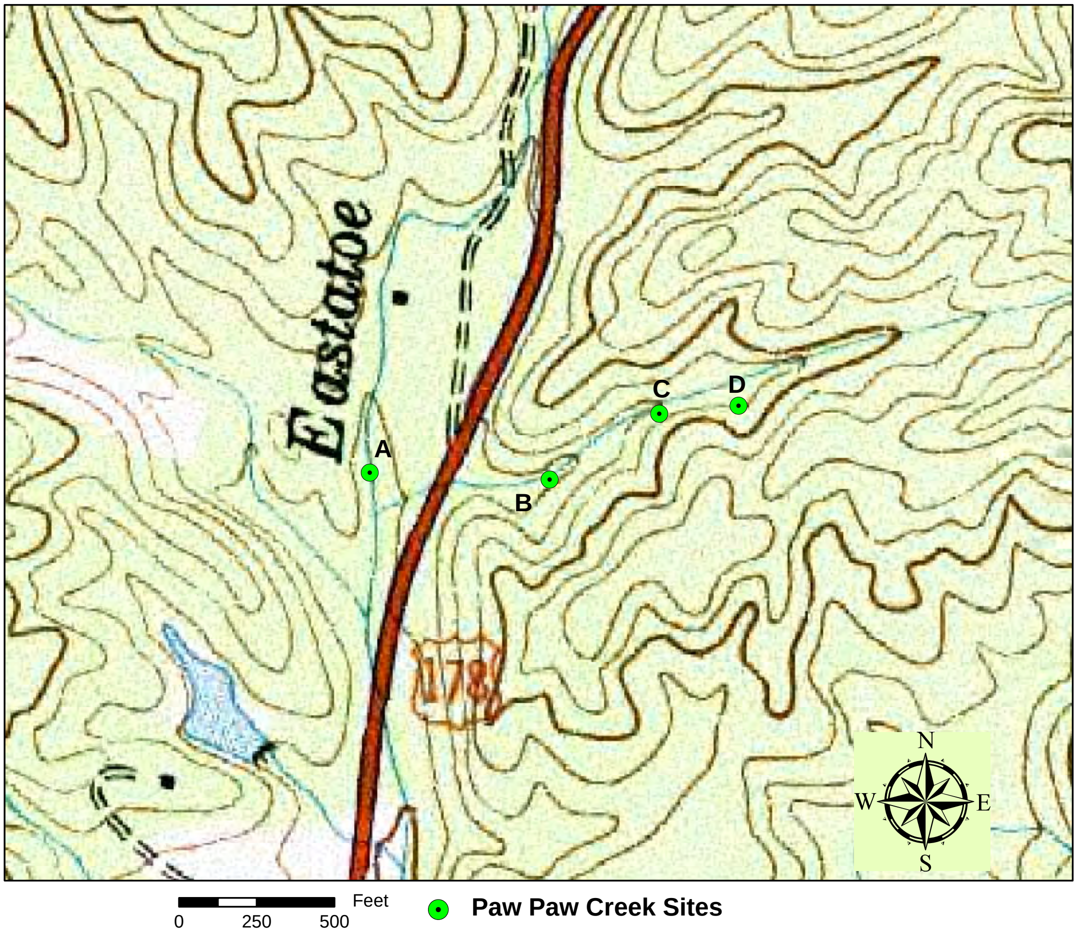



**Figure 31.** Field Trip Locations in the Eastatoe Valley Area

Big Map (figure 32)

Legend

**Field Trip Stop #1: Paw Paw Creek** **35.06605, -82.816467** (all coordinates in NAD 1983)




## Analysis Transect
### Plant Specialist Occurrences

_______________________ _______________________ _______________________

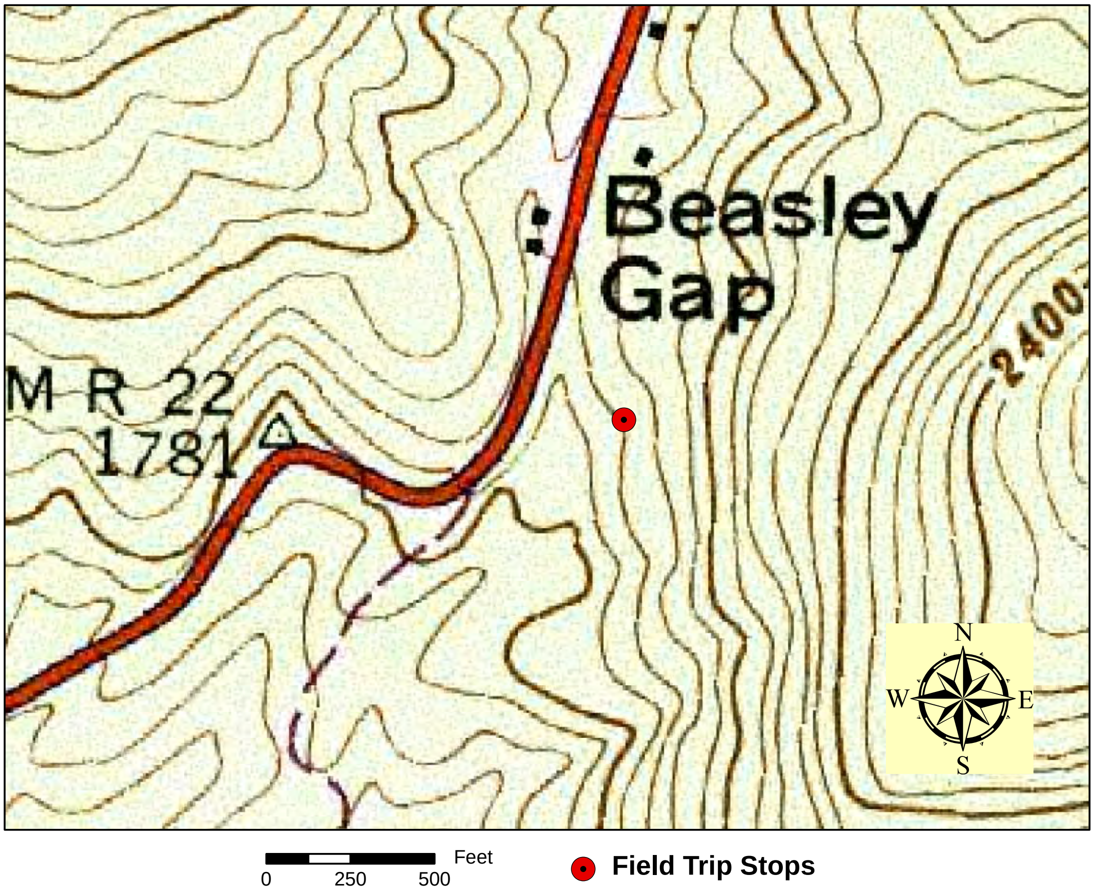
_______________________ _______________________ _______________________

### Soil Examination

| Site A | Site B | Site C | Site D |
|---|---|---|---|
| pH______ | pH______ | pH______ | pH______ |
| Soil color/texture | Soil color/texture | Soil color/texture | Soil color/texture |
| ______________ | ______________ | ______________ | ______________ |

**Substrate**_________________________

**Field Trip Stop #2: Beasley Gap Creek 35.01302, -82.877935**




## Analysis Transect
### Plant Specialist Occurrences

________________________ ________________________ ________________________

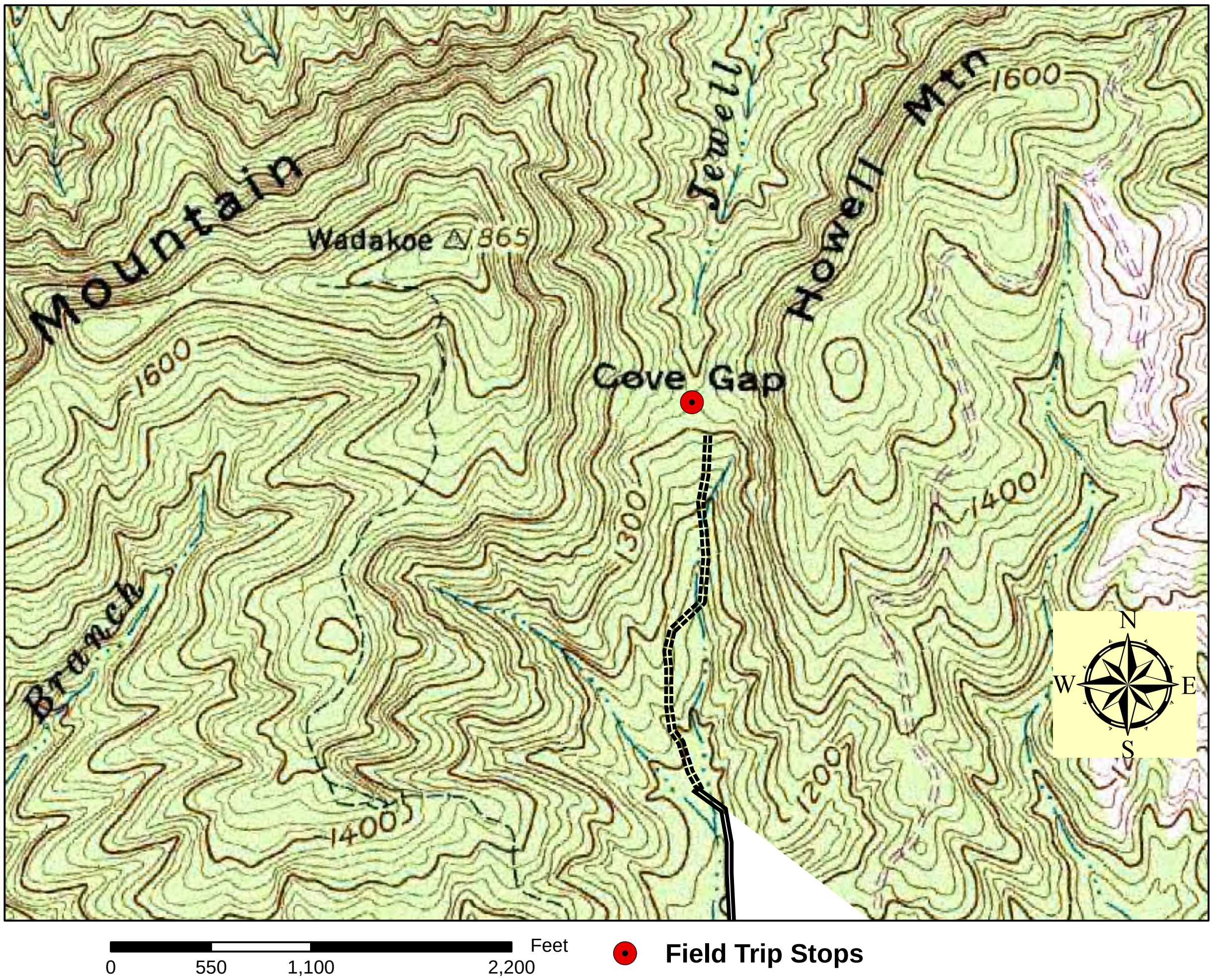
________________________ ________________________ ________________________

### Soil Examination

| Site A | Site B | Site C | Site D |
|---|---|---|---|
| pH______ | pH______ | pH______ | pH______ |
| Soil color/texture | Soil color/texture | Soil color/texture | Soil color/texture |
| _______________ | _______________ | _______________ | _______________ |

**Substrate_____________________________**

**Field Trip Stop #3: Cove Gap on Wadakoe Mountain 34.97824, -82.883181**




## Analysis Transect

### Plant Specialist Occurrences

_________________________ _________________________ _________________________

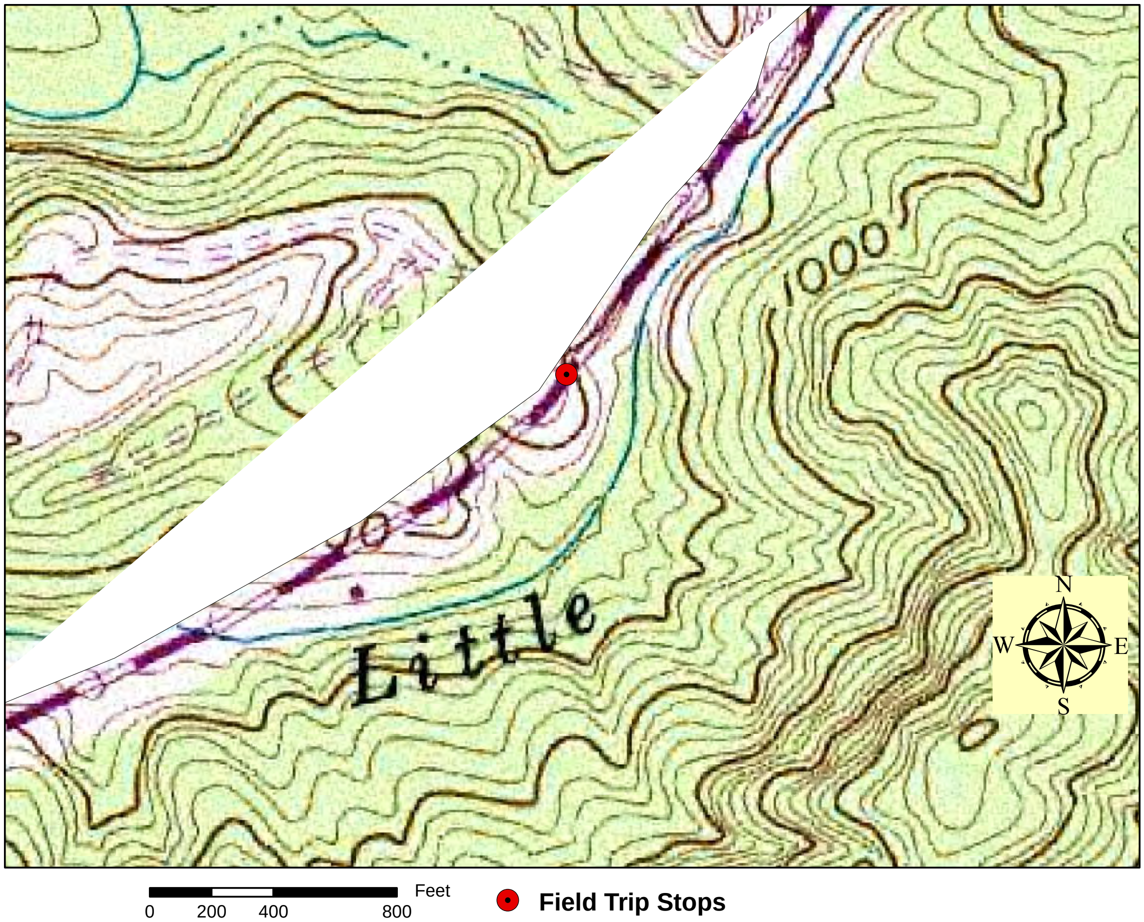
_________________________ _________________________ _________________________

### Soil Examination

| Site A | Site B | Site C | Site D |
|---|---|---|---|
| pH______ | pH______ | pH______ | pH______ |
| Soil color/texture | Soil color/texture | Soil color/texture | Soil color/texture |
| ________________ | ________________ | ________________ | ________________ |

Substrate____________________________

**Field Trip Stop #4: Long Shoals Wayside Park       34.948667, -82.851567**




## Analysis Transect
### Plant Specialist Occurrences

_________________________ _________________________ _________________________

_________________________ _________________________ _________________________

### Soil Examination

**Site A** **pH______**

**Site B** **pH______**

**Site C** **pH______**

**Site D** **pH______**

**Soil color/texture** ________________

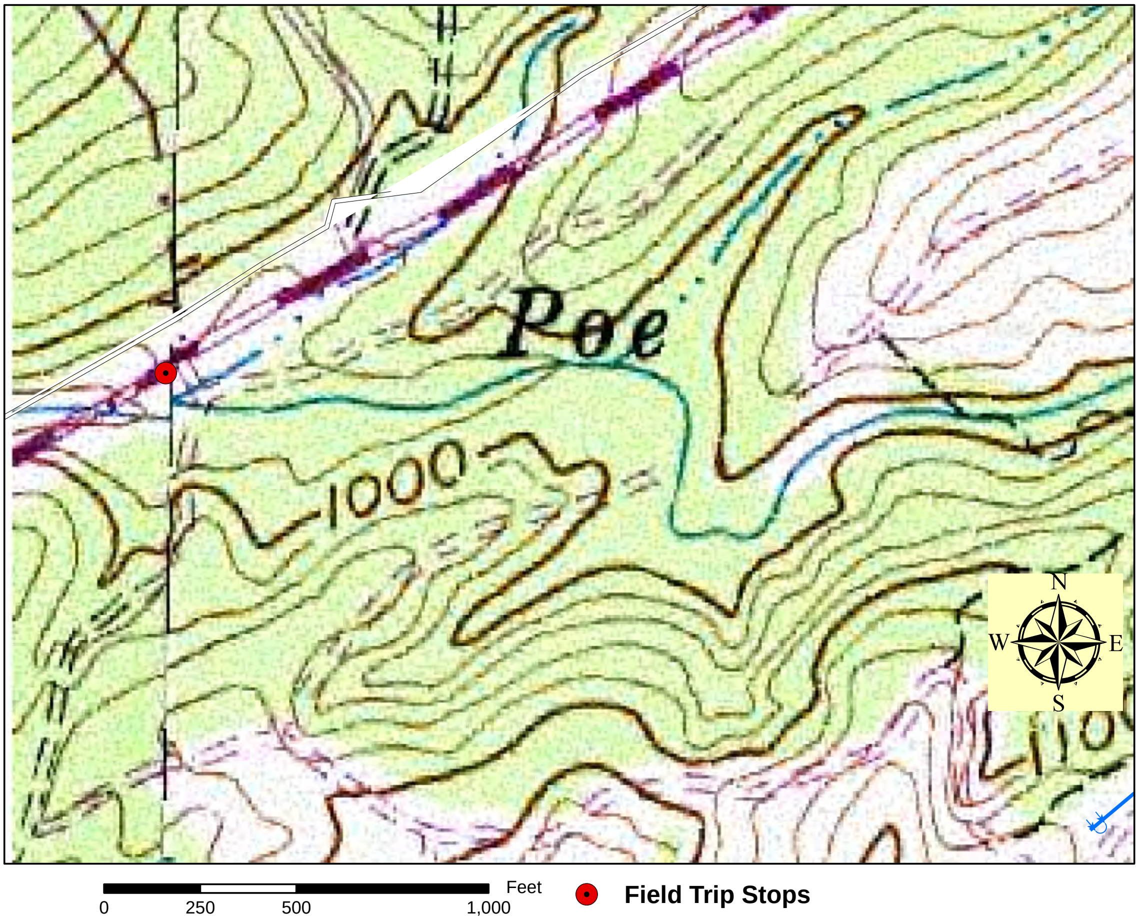
**Soil color/texture** ________________

**Soil color/texture** ________________

**Soil color/texture** ________________

**Substrate____________________________**

**Field Trip Stop #5: Poe Creek 34.9364, -82.874933**




## Analysis Transect
**Plant Specialist Occurrences**

_________________________ _________________________ _________________________

_________________________ _________________________ _________________________

**Soil Examination**

| Site A | Site B | Site C | Site D |
|---|---|---|---|
| pH______ | pH______ | pH______ | pH______ |
| Soil color/texture | Soil color/texture | Soil color/texture | Soil color/texture |
| ________________ | ________________ | ________________ | ________________ |

**Substrate**____________________________